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Separated Stable Isotopes for the Chemist and Biologist

By DAVID W. STEWART*

THE 92 CHEMICAL ELEMENTS are associated uniquely each with its own atomic number, which may be defined as the number of excess positive charges in the nucleus of the atom, or similarly, the number of electrons in the atom's external structure. It is sometimes assumed that the atomic weight of each element, as determined by the chemist, is likewise a fundamental characteristic. Actually, in many instances, an element may exist in several species that differ from each other only in mass. These isotopes (from the Greek words meaning "in the same place") have the same atomic number. Thus, hydrogen is made up of species having relative masses of 1 and 2, occurring naturally in the ratio of about 5000 to 1. Carbon has atoms of 12 mass units mixed with about one per cent of mass 13. Nitrogen is principally mass 14, but also contains mass 15. Oxygen is a mixture of atoms of masses 16, 17, and 18. The heavier elements may contain as many as 10 or more varieties that differ only in mass.

For all practical purposes, the relative abundance of the several isotopes of a given element may be assumed to be the same for samples from all natural sources. Only the most precise measurements show any variation in the characteristic abundance ratio.

Since the isotopes of a given element occupy the same place in the periodic table, it is not unexpected that they should be identical chemically, within the limits of ordinary experimentation. Likewise, except for properties that depend directly upon atomic mass, they have been shown to have almost identical physical characteristics.

If, by laboratory methods, an element is prepared containing an excess quantity of one of its rarer isotopes, the chemical and physical properties remain almost entirely unchanged. If the isotopic material thus obtained is incorporated in a chemical compound, the molecules of the compound undergo the same chemical and biological reactions as would the ordinary substance. However, it is obvious that at any stage of the reaction a quantity of a product may be removed and a determination made of the isotope ratio of the element originally enriched. The presence of this element with an abnormal isotope ratio in a product is thus evidence that this product has been formed from, or brought to equilibrium with, the original material in question. This so-called tracer technic is one of the most important applications of separated stable isotopes that may be

*Research Laboratories, Eastman Kodak Company, Rochester, N. Y.

made by the chemist or biologist. Another field of usefulness is the chemical analysis of complex mixtures by means of the measurement of isotope dilution.

Many chemists have already become familiar with radioactive isotopes as tracers. The most useful of these isotopes are the ones produced by atomic bombardment, but the use of this radioactive material in the routine problems of the average organic or biological chemistry laboratory is still limited by two considerations. Because of the complexity of the apparatus required for atomic bombardment, relatively few institutions can prepare radioactive material in the quantity needed for broad investigations. Moreover, the half-life of radioactive isotopes of several of the most important lighter elements is extremely short. Radio-nitrogen decays to one-half its original intensity in only a few minutes, and radio-oxygen is even shorter lived.

With the commercial production of deuterium oxide, and the recent announcement by the Eastman Kodak Company that N^{15} is now available, separated stable isotopes have become significant tools for research everywhere. In the future, it is planned to make available the separated isotope of carbon, C^{13}, and, possibly, oxygen, O^{18}, and sulfur, S^{34}, as well. When this has been done, a single basic experimental technic will make possible extensive investigations in chemistry, biology, medicine, and other fields. The tracer materials will be just as stable as ordinary chemical compounds, and the factor of time will be eliminated entirely from the tracer technic. The experimental methods employed, and the apparatus required for use with separated stable isotopes, will be described in a later article.

FIGURE 1—*Fractionating column that is used at Kodak Research Laboratories for the separation of isotope N^{15} by chemical exchange. This column is one continuous U-shaped unit, and the total effective length is 80 feet.*

Deuterium, the rare isotope of hydrogen, is, at present, available in better than 99 per cent concentration from the electrolysis of water. General methods for the separation of other light elements have developed along the three lines described herein. A comprehensive review of this work has been published by Urey (*1*).

Since diffusion of a gas depends directly upon the mass of the molecule, the isotopic species of such gases as methane ($C^{13}H_4$, $C^{12}H_4$, etc.), carbon monoxide, nitrogen, etc., may be separated by a suitable thermal diffusion apparatus. The method is capable of producing a relatively high concentration of the rarer isotopes, with a minimum of attention, but it appears to be limited in efficiency by the large expen-

diture of heat energy required for the diffusion process.

A second procedure has been used with considerable success by Urey and his co-workers to separate the isotopes of carbon, nitrogen, and sulfur. This method depends upon small differences in the chemical properties of isotopic molecules. Thus, there is a slight difference between $N^{15}H_3$ and $N^{14}H_3$ in the reaction between ammonia and ammonium salts, in which an exchange of nitrogen occurs. As a result, by bringing ammonia into equilibrium with an ammonium salt solution in an efficient counter-current scrubbing system, the concentration of N^{15} in the ammonium ion can be increased to an extent limited only by the number of successive equilibrations afforded by the apparatus used. The Eastman Kodak Company has set up such equipment for continuous operation, by means of which the N^{15} recently offered for sale is being prepared. To concentrate C^{13}, a similar system involving HCN gas and NaCN solution may be used, while S^{34} is concentrated in the exchange between SO_2 gas and $NaHSO_3$ solution.

A third method, useful in concentrating the rare isotope, O^{18}, is distillation. This process requires the long-continued and unusually efficient distillation of water at low temperatures.

This discussion of the possibilities of research utilizing separated stable isotopes will be continued in later issues of SYNTHETIC ORGANIC CHEMICALS, with a consideration of the experimental technic involved and with reviews of applications that have been made to the problems of organic, analytical, and biological chemistry.

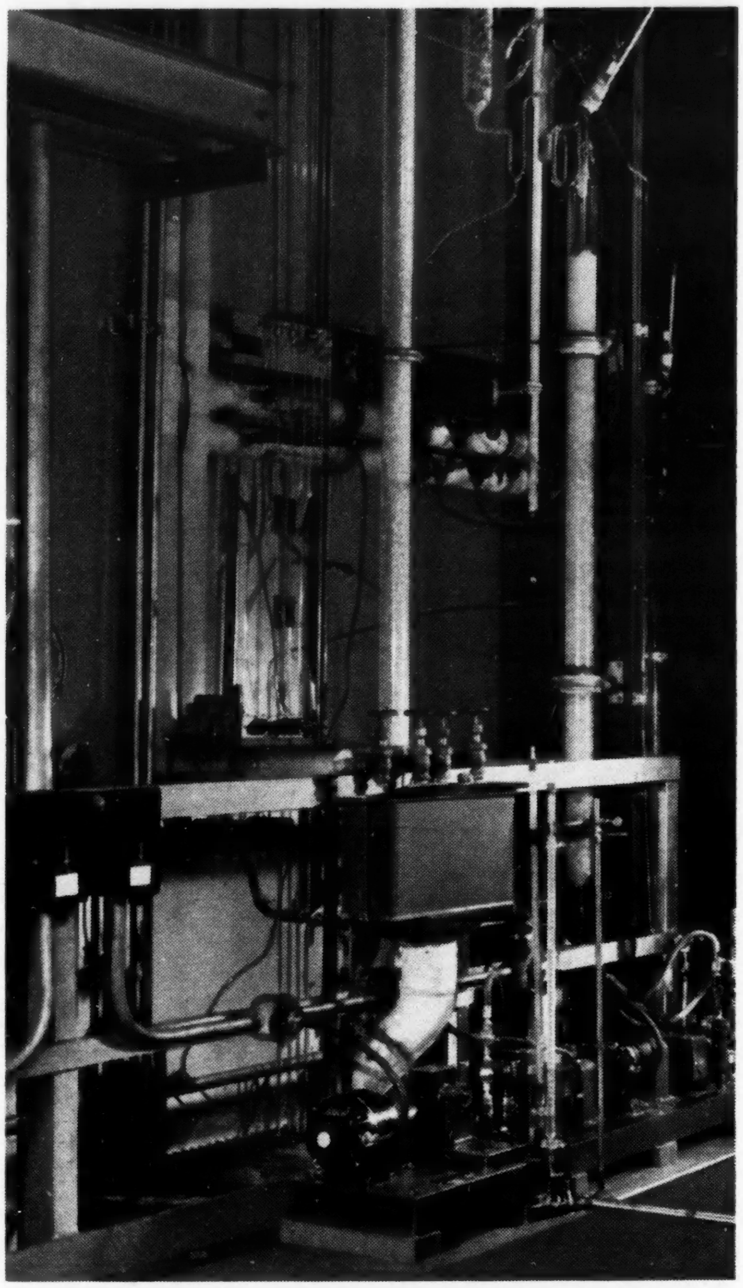


FIGURE 2—*Base of the 80-foot fractionating column shown in Figure 1; note feed pumps.*

Literature Cited

(*1*) Urey, H. C., *Reports on Progress in Physics*, *6*, 48 (1939).

A Mechanical Shaker for Chemicals

IN MANY LABORATORIES, a mechanical shaker is a very important item of equipment. Constructional details of one that can be adapted to meet almost any requirement are presented in the diagrams reproduced on the following page. The principal features of this shaker are its high overload capacity and wide range of applicability. Its sturdy construction and smooth bearings effectively minimize noise and wear, even under heavy loads. The apparatus has been found to be dependable and convenient throughout several years of operation in the *Kodak Research Laboratories*.

The frame of the carriage is formed

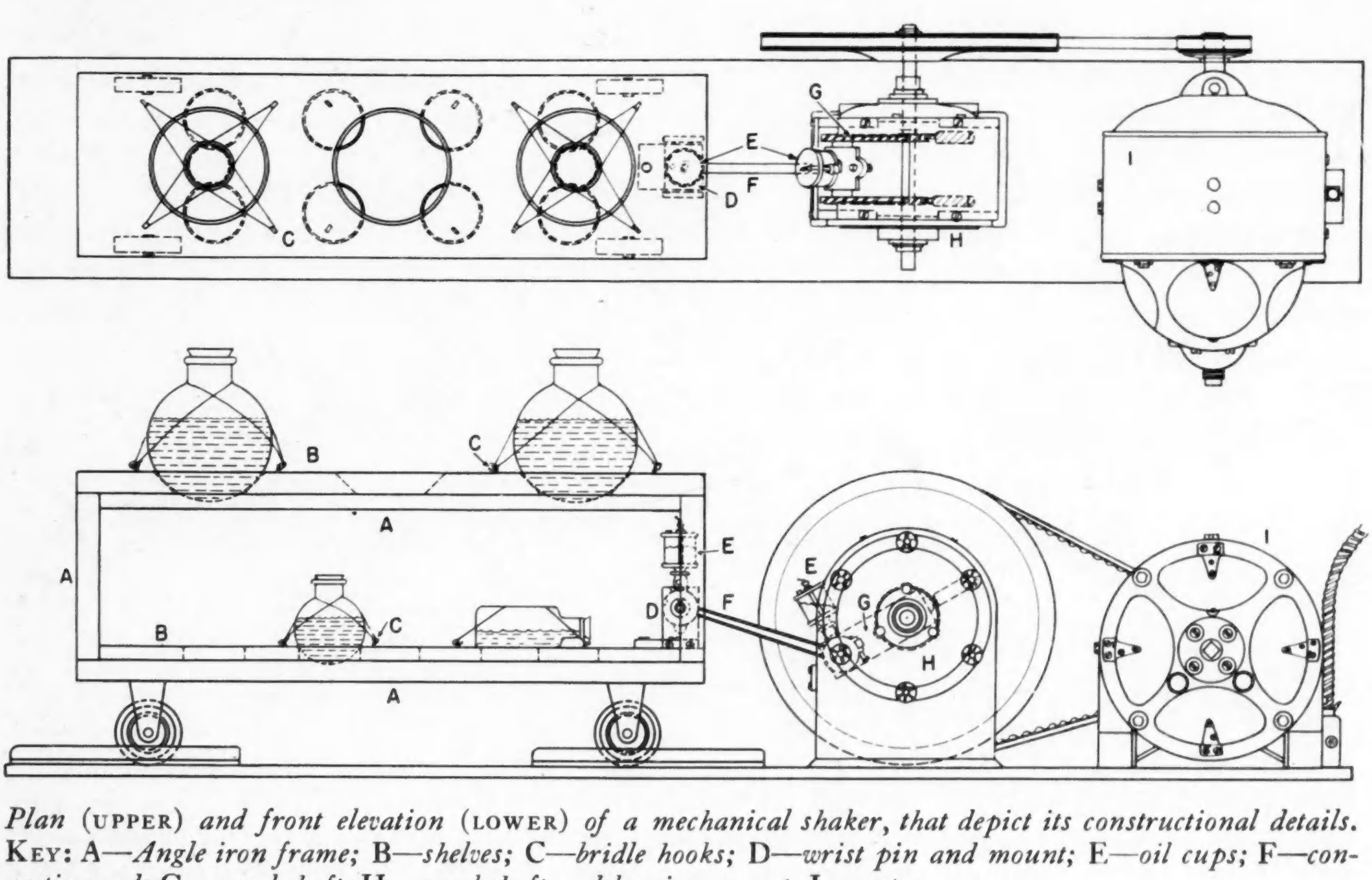
of welded $1\frac{1}{4}$x$1\frac{1}{4}$x$\frac{1}{4}$-inch angle iron; it is about 35 inches long, 12 inches wide, and 12 inches high (outside dimensions), and supports 2 wooden shelves that are attached by bolts. The space between the shelves is about 9 inches, although a 10- to 12-inch clearance might prove more useful. The upper shelf has 3 tapered holes, about 7 inches in diameter; the lower shelf has 8 holes, about $3\frac{1}{2}$ inches in diameter. Flasks of sizes from 500 cubic centimeters' to 12 liters' capacity can be accommodated; they are stabilized by rubber bands or cords extending from their necks to bridle hooks affixed to the shelves near the holes. Bottles, jars, smaller flasks, and test tubes also can be accommodated; and the open-framework design makes it easy to replace the top shelf with accessory platforms for special equipment.

The carriage is supported on 4 stationary rubber-tired casters that are welded to the frame; the casters move in tracks on the base—a piece of $\frac{1}{2}$-inch boiler plate.

The shaker is operated by a 220-volt, low-speed, $\frac{1}{2}$-horsepower, direct-current motor. This type of motor was chosen in order to be certain of having ample power at all speeds. The motor is rheostat-controlled and vaporproof. Power is transmitted from a $3\frac{3}{4}$-inch V-pulley on the motor to a 16-inch V-pulley on the crankshaft, by means of a V-belt.

The crankshaft, bearings, connecting rod, and wrist pin are parts from a Delco home lighting plant. Counterbalances were added to the crankshaft, and it was found necessary to provide slow-drip oil cups for the wrist-pin and connecting-rod bearings. The crankshaft bearings are in their original mounts, which are bolted to boiler-plate uprights that are welded to the base.

The apparatus has a 5-inch stroke; it usually operates at 100 strokes per minute, but satisfactory performance can be obtained at considerably higher or lower speeds. Because of the sturdy construction, few repairs have been necessary. Replacement parts have been easily and economically obtainable, since the items that are subjected to wear are normally commercially available.



Plan (UPPER) *and front elevation* (LOWER) *of a mechanical shaker, that depict its constructional details.* KEY: A—*Angle iron frame;* B—*shelves;* C—*bridle hooks;* D—*wrist pin and mount;* E—*oil cups;* F—*connecting rod;* G—*crankshaft;* H—*crankshaft and bearing mount;* I—*motor.*